Renewable and Sustainable Energy Reviews 24 (2013) 131–141

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

# The impact of international forces on the Chinese wind power industry

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ARTICLE INFO

*Article history:*
Received 17 January 2013
Received in revised form
14 March 2013
Accepted 18 March 2013
Available online 11 April 2013

*Keywords:*
China
Wind power industry
International cooperation
CDM
Import and export

ABSTRACT

The Chinese wind power industry has achieved remarkable growth in the last two decades. The total installed capacity of wind power in China has now surpassed that of the United States thereby making it the country with the largest installed wind power capacity in the world. The independent and innovative capability of Chinese wind turbine manufacturers has undergone continuous improvement and has now reached the point where the country has the capability to produce large scale wind turbines. Although the Chinese domestic policy incentive has played a significant role in the rapid development of the Chinese wind power industry; the contribution made by external international forces should not be overlooked. This research aims to establish a comprehensive model reflecting the international forces that impact on the Chinese wind power industry. This model consists of three subsystems, i.e. (1) the international cooperation subsystem, (2) the Clean Development Mechanism (CDM) subsystem and (3) the import/export subsystem. Using the model as part of the research, the findings suggest that for the international cooperation subsystem, joint research and development (R&D) and information sharing provide both the finance and the technologies for the entire Chinese wind power industry. The financing impact of CDM certainly guarantees the profitability of wind power projects; however its effect in terms of the diffusion of technical information and technical capability is weak. Similarly, the degree of dependence of Chinese wind turbine manufacturing on imports is weakening as domestic wind turbine manufacturers actively explore overseas markets. This comprehensive model helps both international and domestic wind power investors to understand the impact of international forces on the Chinese wind power industry resulting in better investment decisions and the consequential minimization of risk.



**Contents**



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1364-0321/$ - see front matter © 2013 Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.rser.2013.03.055

## 1. Introduction

The Chinese wind power industry has attracted worldwide attention during the last two decades. China has now surpassed the United States of America to become the largest country in terms of wind power with the total installed capacity reaching 65 GW in 2011 [1]. Similarly, in terms of wind power investment, China has assumed the mantle as the largest global market on the back of the rapid growth of Chinese wind turbine manufacturers (WTMs) [2]. China is also the largest Certification Emission Reductions (CERs) provider in the world, where more than half of the CERs are provided by wind power projects [3]. It is not surprising then that the Chinese wind power industry has attracted attention from the international community in aspects such as enhancing energy supply, reducing greenhouse gas emissions, and stimulating economic growth.

There have been extensive studies conducted on the international forces that impact on the development of the wind power industry. For instance, Zhao et al. [4] established a diamond model to study the cooperation between the wind power industry in China and that of other countries. Similarly, Zhao et al. [5] investigated the role of international cooperation policies on the development of the Chinese wind power industry, from the perspective of renewable energy development. Zhang et al. [6] conducted an economic evaluation of Chinese wind power projects and discussed the issues associated with the recognition of the Clean Development Mechanism (CDM) qualification. Yang et al. [7] evaluated the impacts of the uncertain CDM income on the net present values (NPVs) of Chinese wind power projects, within the context of uncertain international energy policies. Zhao et al. [8] discussed the characteristics of Chinese domestic wind turbine manufacturers (WTMs) compared to foreign wind turbine manufacturers, and subsequently established an analytical hierarchy model to assess their advantages and disadvantages in terms of competitiveness in the Chinese market. Ru et al. [9] explored the driving forces underlying wind power technology development by reviewing the transition of the innovation modes (i.e. China buys technology from another country, studies it and improves it to fit into the Chinese situation) and its dynamic interactions with technology capability, innovation ability, market formation, and wind power policy. These studies provide an analysis of factors affecting the Chinese wind power industry development from single perspectives only, e.g. international cooperation, international policies, CDM and international competition. There is clearly a lack of studies about how these international forces integrate with respect to their influence on the Chinese wind power industry. To some degree this is not surprising as the international forces form such a complex system that, to date no one has conducted such a comprehensive analysis.

This study aims to fill this gap in the knowledge by reviewing the integrated impacts of international forces on the Chinese wind power industry and establishing a model that will help to explain how these international forces impact on the Chinese wind power industry. The classification of the complex international influences provides useful inputs for achieving the sustainable development of the wind power industry.

## 2. The Chinese wind power industry chain and international forces model

### 2.1. The Chinese wind power industry chain

As a complete industry system, the Chinese wind power industry chain consists of the upstream, the midstream and the downstream enterprises that are both interactive and interdependent [10] (see Fig. 1). According to Fig. 1, the upstream of the industry chain comprises the raw materials and parts enterprises that mainly produce gears, bearings, blades, tower and control systems etc. The industrial midstream enterprises are responsible for designing, developing and testing wind turbines, then assembling those components to form a kit of completed parts. The downstream of the industry chain involves the wind farm construction and operation enterprises, including wind power projects development, grid connection and the selling of electricity.

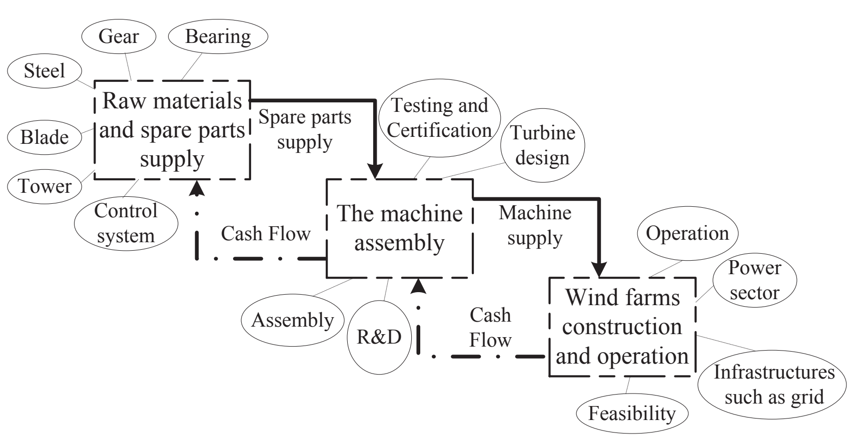


**Fig. 1.** The Chinese wind power industry chain structure and cycles [11–14].

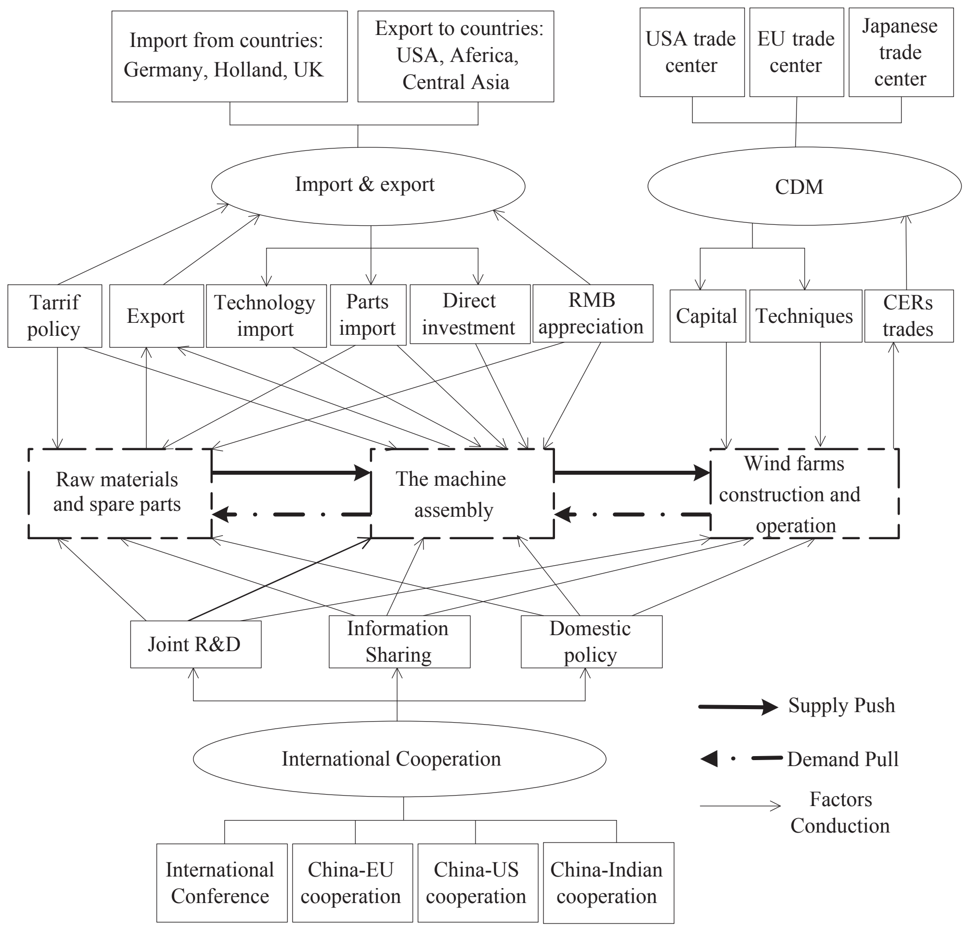


**Fig. 2.** International forces model depicting how these forces affect the Chinese wind power industry [4–14].

In China, the upstream and midstream enterprises are making efforts to enhance Research and Development (R&D) capacity so as to provide the wind farms with reliable components and high performance turbines, thereby enhancing the steady development of wind farm construction and operation. This pressure on the upstream and midstream is compounded by the large domestic demand for wind power in China resulting in increased monetary investment and the supply of parts to fulfill this demand. The upstream enterprises provide parts and machine flow to the midstream and downstream enterprises which in turn feed cash flow back to the upstream enterprises. This forms an effective industry cycle. Due to its cyclical structure [11], every single part of the wind power industry is affected by environmental forces, including international forces. Through the Supply-push and Demand-pull mechanism, the international forces may affect other parts as well.

### 2.2. The international forces model of the Chinese wind power industry

This study establishes the interactive mechanism model between the Chinese wind power industry and international forces (see Fig. 2). The model has taken the life cycle of the Chinese wind power industry into consideration e.g. from parts manufacturing, to machine assembly through to the construction and operation of wind farms. The established model consists of three international forces, i.e. international cooperation, the CDM, and import/export. The upstream enterprises provide parts and machine flow to the midstream and downstream enterprises in order to promote the development of downstream enterprises, which is defined as Supply Push. In return, the downstream enterprises feed cash flow to the upstream enterprises to funding their promotion, which is defined as Demand Pull. The three international forces and wind power industry interact with each other through the channel of Factors Conduction. These international forces and their impacts on the Chinese wind power industry will be identified and analyzed in the following sections.

## 3. The influence of international cooperation

China has actively participated in the International Conference on Climate Change and is currently in the process of establishing bilateral and multilateral energy cooperation mechanisms with both developed and developing countries [7], signing international and national agreements and developing policies to promote wind power development [5]. China has also established joint R&D mechanisms with other countries not only at government level but also with enterprises within those countries.

### 3.1. China participates in multilateral international cooperation

Recent decades have witnessed the growing awareness of and concerns about climate change. Many Governments are now actively cooperating with each other in an effort to deal with the impacts of global warming. The United Nations Conference on Environment and Development was held in Rio, Brazil in 1992. That conference approved the United Nations Framework

Convention on Climate Change (UNFCCC). This was the first worldwide international convention on the control of greenhouse gas emissions to deal with global warming. December 11, 1997 saw the first legally binding emissions reduction agreement, the Kyoto Protocol, which included International Emissions Trading (IET), Joint Implementation Mechanisms (JIM) and Clean Development Mechanisms (CDM) [15]. The Kyoto Protocol has specific provisions about the types of greenhouse gas emission (GHG) reduction and a schedule and amount of emission reductions for major developed countries. The agreement followed the principle of "common but differentiated responsibilities" [16]. Developed countries took the lead in emission reduction targets. China, as a developing country, does not bear the responsibility of emission reduction targets, accorded by the Kyoto Protocol.

Since 2000, China has taken steady action to respond to the International Conference on Climate Change. In 2007, the United Nations Climate Change Conference passed the "Bali Road Map", which proposes technology development and transfer as well as funding incentives for climate change adaptation. These incentives are becoming significant for the further implementation of the Convention. During this conference China became the first ever developing country to issue a National Climate Change Program when it announced the "Chinese National Climate Change Programs" [17]. This program comprised a national level group consisting of senior officials to respond to climate change. The result saw a promulgation of a series of laws and regulations about climate change.

One of the actions taken by China as a result of the national climate change program was to regulate the energy structure by assigning a higher development priority to wind power thereby increasing the proportion of renewable energy provided by wind. In November 26, 2009, Premier Jia-bao Wen, made carbon reduction a commitment by announcing that carbon emissions per unit of GDP in 2020 would fall by 40% to 45% of those in 2005 [18]. In 2009, the United Nation Climate Conference (Copenhagen Summit) was held in Copenhagen, Denmark. The main agenda of the Copenhagen Summit included: (1) the emission reduction amount for industrialized countries; (2) the approach of China, India and other major developing countries in reducing emissions; and (3) financing developing countries [19]. During the Copenhagen Summit, China made a positive commitment to new policies. Driven by these active policies, China was able to increase its annual wind power generating capacity from 12.8 billion kW h in 2008 to 50.1 billion kW h in 2010 [20]. China has clearly recognized wind power as a major force in the energy revolution and as an effective action to deal with global warming issues.

### 3.2. The joint R&D mechanism

The Chinese wind power industry has had to rely on developed countries to import core technologies and has had to customize this technology to suit the local conditions [5]. These are a number of issues associated with this approach, not the least of which being the high level of cost [21]. Furthermore, most of the wind power technologies have been introduced via licensing agreements which means that domestic manufacturers are not allowed to grasp the core technologies [22]. These issues can be mitigated by embarking on a joint R&D program or mechanism which is beneficial to all parties involved in the program.

China has established joint R&D mechanisms with developed countries such as the United States, Japan and the European Union, and developing countries such as India and Brazil. Joint R&D mechanisms include government summits, academic forums and cooperation between enterprises. Under this approach, a strategic framework is determined by the summit and this is followed by policy support provided by a government department. These initiatives are implemented by local governments, research institutions and enterprises. As shown in Table 1, the renewable energy cooperation between China and the United States and between China and the EU ranged from government level to enterprise level.

From the Chinese Wind Turbine Manufacturers' (WTMs) point of view, the core technology and cost present major bottlenecks to the development of the Chinese wind power industry [25]. Through joint R&D mechanisms, WTMs are quickly able to master advanced technology, thereby accelerating the upgrading of the Chinese wind power industry. Similarly, it enhances the manufacturers' own R&D capabilities. By researching and transforming foreign advanced wind power technology, the wind turbine manufacturing industry in China has been able to produce a single unit wind turbine with the production capacity of 6 MW. This is considered globally to be at the cutting edge of wind power technology.

**Table 1**
Major renewable energy cooperation types between China–USA and China–EU [5,23,24].

| Type | China–USA cooperation | China–EU cooperation |
|---|---|---|
| Government cooperation | • China–USA Strategic Economic Dialogue (2006 to present)<br>• China–USA Energy and Environment Center (2003 to present)<br>• China–USA Conference on Climate Change Working Group (2003 to present)<br>• China–California clean energy dialogue mechanism (2005 to present). | • China–EU annual summit mechanism (1998 to present)<br>• China–EU energy dialogue (2005 to present)<br>• China–EU Business Summit mechanisms (2009 to present)<br>• The EU–China Energy Cooperation Joint Statement (2009 to present). |
| Officials and the public integrated cooperation | • China–USA Clean Energy Technology Forum (2001 to present)<br>• Renewable Energy Partnership (2010 to present)<br>• China–USA Clean Energy Joint Research Centre (2009 to present) | • Energy-saving training courses (2002 to present)<br>• Energy technology and development seminars (2007)<br>• China–EU Energy and Environment Project (2004 to present) |
| Non-governmental organization | • The Ford Foundation (1988 to present)<br>• Energy Foundation (1999 to present)<br>• EcoLinx Foundation (2003 to present) | • EU–China CDM promotion project (2007 to 2010)<br>• China–EU renewable energy college projects (Signed in 2009) |
| Multilateral cooperation | • The Asia-Pacific Clean Development and Climate Partnership Plan (2006 to present)<br>• International Methane to Markets Partnership Plan (2004 to present)<br>• The Global Environment Facility (GEF) (1991 to present) | • The meeting of Asian and European energy security (2009 to present)<br>• Near-zero-emission technology development and demonstration (2006 to present)<br>• Carbon capture and storage technology cooperation action plan (2006 to present) |

For wind farm operators, connection to the power grid presents a major risk factor simply because of the fickle nature of the wind and the lack of certainty that the wind will be there all the time. Indeed, reinforcing grid infrastructure presents one of most significant challenges to the wind power developments in China. However, there is no direct evidence that delays in reinforcing or establishing grid connections are influencing the behavior of international firms, which in turn, influence the behavior of domestic firms. Advanced technologies such as Low Voltage Ride Through and Smart Grid System have achieved rapid development in the international wind power industries [26]. Through joint R&D, the Chinese wind power industry can learn (from advanced wind power technologies) how to achieve large-scale wind power connection to the power grid. With the increase of on-grid wind power generation capacity, the wind farm will demand more wind turbines from upstream enterprises (the wind turbine manufacturers) and the development of WTMs will be further promoted through this demand pull mechanism.

There are a number of issues, however, associated with joint R&D mechanisms, not the least of which is the perennial issue of intellectual property [27]. The ultimate purpose of the joint R&D is the research and development of new products and technologies to improve the overall development level of the wind power industry. During the commercialization process, the critical condition to sustain continuous cooperation is the protection of the technological intellectual property rights of all participating parties. Accordingly it is imperative to reinforce intellectual property protection by means of legislation.

### 3.3. Information sharing platforms

Information is an essential resource for economic and technological development and the lack of reliable information has become one of the major obstacles restricting the further development of the wind power industry [28]. As a technology and capital-intensive industry, the wind power industry relies on detailed and reliable information. By having reliable information, investors can reduce the investment uncertainty.

Therefore, the information-sharing platform is a favorite when promoting the development of the Chinese and international wind power industry. In general, it takes two to three years to collect wind energy resources and environmental statistics, prior to the development of a wind farm. The more detailed and accurate the statistical data, the more effective the construction and operation of the wind farms. In 2000, the European Energy Technology Promotion Network (OPET) opened up to China. The Guangzhou and Zhejiang Energy Research Institutes of the Chinese Academy of Sciences signed a contract with the EU to become associate members of OPET [29]. Through these two institutes, China is now able to communicate energy related technical information with Europe. Information sharing platforms, which provide wind energy and environmental information now play a critical role in promoting wind power bidding and tendering, increasing the amount of investment in wind power and in reducing risks derived from asymmetric (unevenly distributed) information.

Currently China does not have an established comprehensive information sharing platform accordingly, only small amounts of wind power project bidding information can be obtained from websites of companies and associations such as the Chinese Wind Energy Association. The information that is available is often scattered which further increases the cost of information collection.

## 4. The influence of clean development mechanism (CDM)

The clean development mechanism (CDM) is another critical factor to promote the development of the Chinese wind power industry [30]. CDM projects provide additional funding for wind power projects thereby helping to reduce investment uncertainty [31]. Furthermore, the effect of “small capital leveraging big investment” stimulates wind power investment. Technology transfer and technology diffusion, brought about by CDM projects also provide some core technologies for the Chinese wind power industry [32]. Under the CDM scheme, Chinese wind power projects can apply for Certified Emission Reductions (CERs), which can be traded in the international carbon trading market. Currently, China is the largest CERs provider in the international carbon trading market [33] where the amount of Chinese CERs account for more than half of the total market thereby providing strong support for international carbon trading.

### 4.1. CDM project funds for the construction of wind farms in China

As a clean energy source, wind power is a relatively mature technology with a comparatively short development cycle [34]. These characteristics are in line with the requirements for funding support as prescribed in the provisions of the CDM. By December 31, 2009, 2279 projects had been approved by the National Development and Reform Commission as CDM projects, 336 of these being wind power projects [35]. The number of Chinese wind power projects registered by the CDM Executive Board (EB) of the United Nations Framework on Climate Change Convention, reached 140 by the end of 2009.

CDM projects provide additional income for renewable energy enterprises, especially wind power enterprises. This additional income is attractive to wind power investors. For example, a wind power farm with an installed capacity of 50,000 kW and on-grid capacity of 100 million kW h can reduce the $CO_2$ emissions by 100,000 t every year [36]. As a result, the annual emission reduction revenue is 10 million Yuan, which is equal to a subsidy of 0.1 Yuan per kW h. Currently, the Chinese wind power industry would gain more than 420 million U.S. dollars through transferring CERs if all wind power projects successfully registered by the CDM executive Board were carried out smoothly [37].

As two of the largest Chinese wind farm operators, Huaneng Renewable Co., Ltd. and China Datang Corporation Renewable Power Co., Ltd. have gained increasing amounts of income from CDM projects since 2007. As shown in Table 2, Datang's CDM revenue accounts for 10% of pre-tax profits. Additional revenue from CDM projects brings profit to the Chinese wind power enterprises that provide funds to the business operation.

In addition, CDM projects provide a variety of financing channels for Chinese wind farms. These include forward buying, CERs purchase agreement or contract, deposit-CERs purchase agreement, international fund, direct investment and finance leases [41]. These channels ensure finance for both the Chinese wind power industry and the wind farm operation.

**Table 2**
CDM revenue and proportion of pre-tax profits of Huaneng and Datang 2007–2010 [38–40].

| Year | Huaneng Renewable Co., Ltd. | | China Datang Corporation Renewable Power Co., Ltd. | |
|---|---|---|---|---|
| | The CDM revenue (million Yuan) | Proportion of pre-tax profit (%) | The CDM revenue (million Yuan) | Proportion of pre-tax profit (%) |
| 2007 | 110 | 4.6 | 3,320 | 16.0 |
| 2008 | 1620 | 17 | 7,160 | 15.5 |
| 2009 | 2870 | 9.5 | 13,700 | 16.0 |
| 2010 | > 20000 | > 22.6 | 23,000 | 9.66 |

Therefore, Chinese wind power investors can obtain a certain level of enhanced profitability from CDM projects, which attracts other investors to develop wind farms. The developers then demand better wind turbines. This demand motivates increasing number of Chinese wind power manufacturers to invest in R&D and has led to a substantial improvement in the quality of Chinese wind turbines.

### 4.2. CDM and wind power technology transfer

There are two aspects of technology transfer type with respect to CDM projects, i.e. equipment transfer and knowledge transfer [42]. Technology transfer plays an important role in the Chinese wind power industry, from both the up and down-streams of the supply chain. Through CDM projects, wind farms can secure key technologies and equipment for grid connection that are generally claimed in Projects Design Documents (PDDs). This helps to resolve the difficulty of grid connectivity, which often presents a significant obstacle for the sustainable development of the wind power industry in China [43]. In addition, the development of wind farms demands more wind turbines. Therefore, it helps to absorb what used to be the overcapacity of wind turbine manufacturers (WTMs).

CDM aims to cut down the cost of wind power technology diffusion, thereby encouraging that diffusion; especially from developed countries to developing countries. Antoine et al. [44] provided an assessment of the technology transfers that took place through the CDM using a data set of 644 registered projects. Their study found that technology transfer mainly covers two areas, i.e. non-$CO_2$ GHG emission reduction and wind power. They also found that Mexican and Chinese projects are the major attractors (importers) of technology transfer whereas European countries are the main technology suppliers.

There is no evidence however, that such technology transfer is primarily caused by CDM projects. Driven by governmental policies, China has gradually implemented technology transfer for wind power since 1986 [45]. However, leading Chinese wind power equipment manufacturers still purchase technology licenses from European countries, e.g. Goldwind (China) purchases technology licenses from Repower (Germany) and Vensys (Germany), whereas Sinovel (China) purchases from Wendtec (Germany). Around half of these wind power projects in China claimed technology transfer in their Projects Design Documents (PDDs); this is much higher than the world average level of one third [33]. Because technology transfer is dependent on purchasing from foreign enterprises has meant that the cost of Chinese wind power projects has had to increase.

### 4.3. CERs trading

Certification emission reductions are greenhouse gas emission reduction certificates issued by the United Nations Executive Board to those enterprises that implement CDM projects, through designated confirmed operational entities. The CERs' price is mainly influenced by the supply and demand requirements of the market [46].

The development of the Chinese wind power industry has turned China into the world's largest CERs provider with some 40–50% of the world's total CDM market [47]. This has had 2 effects i.e. on the one hand it has increased the amount of carbon trading in the international market, but on the other hand it has reduced the carbon trading price.

### 4.4. Rejection of Chinese CDM project applications and expiration of the Kyoto protocol

The further development of Chinese CDM projects is facing some new obstacles. Two of the most significant barriers are the rejection by the United Nations Executive Board (EB) to register some of China's CDM projects and the risks associated with the expiration of the Kyoto protocol.

Prior to the Copenhagen Summit, the 51st session of the United Nations Executive Board (EB), in charge of the carbon trading and CDM project approval, rejected the registration of 10 Chinese wind power CDM projects (see Table 3). According to the EB official report, the projects were rejected because, "(as) cannot according to the project participants and DOEs (DOE) provided the information to evaluate the reasonableness of the cost, and the additionality of these projects have not been proven (and thus) cannot be granted registration" [48]. Fundamentally the EB questioned the whether the Chinese really needed this additional subsidy to make their wind power industry viable i.e. there was a feeling that the EB subsidy was not a requirement of the Chinese wind power CDM projects as it asserted that the Chinese government manipulated the wind power tariff and investment. Subsequently, the Chinese government commissioned the Chinese–Danish Wind Energy Development Project Office and the China Renewable Energy Professional Committee to jointly develop a R&D report on the Chinese wind power and electricity price in order to provide an explanation to the EB about the wind power electricity price policy and power coefficient standard in China. The EB however has retained its original decision. This will mean that in the future it will be more difficult to apply for wind power CDM projects and this will reduce the attractiveness investing in the Chinese wind power industry.

More importantly, the first commitment period of the Kyoto protocol, which is regarded as the official document of the United Nations dealing with climate change ceased at the end of 2012 [49]. Developing countries, including China, generally support that the second commitment period of the Kyoto Protocol commence from 2013. However, other countries such as Japan, Russia and Canada are against this proposal. Along with the expiration of the Kyoto Protocol, many uncertainties are emerging, e.g. whether the wind power CDM

**Table 3**
10 Chinese wind power CDM projects rejected by the EB [48].

| Project | Address | Project owners | Capacity (MW) |
|---|---|---|---|
| Huitengliang Phase II Wind Power Project | Inner Mongolia | Datang Hebei Power Company Limited | 49.5 |
| Siziwangqi Bayin'aobao Wind Power Project | Inner Mongolia | China Guodian Corporation | 49.5 |
| Bayannaoer Chuanjingsumu Wind Power Project | Inner Mongolia | China Longyuan Power Group Corporation Limited | 49.3 |
| Guohua Tongliao Kezuo Zhongqi Phase I Wind Farm Project | Inner Mongolia | Guohua Energy Investment Co., Ltd. | 49.5 |
| Huadian Kulun Wind Farm Project | Inner Mongolia | China Huadian Corporation | 201 |
| Fujin Phase II Wind Power Project | Heilongjiang | Zhongyufujin Wind Power Co., Ltd. | 18 |
| Yichunxiaochengshan wind power Project | Heilongjiang | Yichun Longyuan Wind Power Co., Ltd. | 49.3 |
| Heilongjiang Yilan Hezuolinchang Wind Power Project | Heilongjiang | Yilan Longyuan Wind Power Co., Ltd. | 24.65 |
| Changtu Quantou Wind Power Project | Liaoning | China Longyuan Power Group Corporation Limited | 49.3 |
| Huadian Xiaocaohu the 2nd phase of No.1 Wind Farm project | Xinjiang | China Huadian Corporation | 49.5 |

projects are valid, and whether the existing CDM projects will continue. These uncertainties will have serious effects on wind power development and exacerbate investment risks.

## 5. The influence of the import and export

The import/export system of wind power equipment and technology is another international force affecting the Chinese wind power industry. Foreign direct investment provides advanced technology and expertise necessary for the success of wind power developments [50]. The Chinese government has released preferential import tariff policies based on the different stages of the Chinese wind power industry, to enable the importation of key components and core technologies [51]. Similarly, the Chinese wind turbine manufacturers (WTMs) have developed to a scale and level where they can now export wind turbines and equipment at a competitive price to overseas markets [8]. Similarly, the fluctuation of international exchange rates is also affecting the development of the Chinese wind power industry.

### *5.1. Foreign wind turbine manufacturers investing directly in China*

The global wind power market is growing rapidly as echoed by the increasing demand for wind power in China. Consequently many leading wind turbine manufacturers have gradually entered the Chinese wind power market. Table 4 shows the largest 5 foreign wind power turbine enterprises in terms of total installed capacity. The leading manufacturers, such as Vestas (Demark), Gamesa (Spain) and GEwind (United States) have also established factories in China. In 2010, these 5 manufacturers' total installed capacity accounted to 17.5% of the Chinese wind power market. This market share declined slightly in 2011.

**Table 4**
The top 5 foreign wind power equipment enterprises in China [52–55].

| Enterprises | Location | Year entered China | Accumulated installed capacity market share | |
|---|---|---|---|---|
| | | | 2010 (%) | 2011 (%) |
| Vestas | Beijing | 1999 | 6.5 | 5.7 |
| Gamesa | Tianjin | 2005 | 5.4 | 4.5 |
| GE wind | Shanghai | 2005 | 2.6 | 2.5 |
| Suzlon | Shanghai | 2009 | 1.8 | 1.4 |
| Nordex | Xi'an | 1998 | 1.2 | 0.9 |

Foreign wind turbine manufacturers (WTMs) that own core wind turbine technologies and have abundant management experience can enjoy the lower labor cost advantage and a surplus of surplus of very well-qualified engineers (e.g. mechanical and electrical engineering graduates) in China and avoid having to import wind power equipment. This is beginning to have a significant effect on the Chinese wind power supply market.

Initially, some favorable policies had given the Chinese local WTMs advantages over foreign WTMs in the Chinese market. For example, the National Development and Reform Commission (NDRC) issued a policy that required the construction of wind farms to have at least of 70% of their wind turbine equipment manufactured in China in order to gain the project approval [56]. However, in December 2009, this regulation was abolished in an effort by the Chinese Government to attract more foreign WTMs.

### *5.2. Chinese enterprises importing overseas advanced technology*

Through technology licensing and joint research and development agreements, Chinese WTMs are now able to access foreign core technologies. Table 5 shows the source of the technology for the top 10 enterprises in China in terms of total installed capacity. As shown in Table 5, the majority of wind power technologies utilized in the Chinese wind power industry are imported from foreign countries, either by technology licensing and/or joint R&D agreements. Only one of the top 10 domestic manufacturers has adopted an independent R&D approach.

There are a variety of imported wind turbine technologies, ranging from 600 kW to 3600 kW with the 1500 kW turbine technology being the most popular. Sinovel, Goldwind and Dong Fang Turbine, the top 3 WTMs in China, import 1500 kW wind turbine technology from Germany. In addition, Sinovel jointly develops and researches 3000 kW wind turbine technology with Wentec (Germany), and Dong Fang Turbine imports 2500 kW technology from Wentec (Germany).

Some companies do not have exclusive arrangements in terms of technology importation and joint R&D as evidenced by United Power and Mingyang Electric who both cooperate with Aerodyn (Germany) for the research and development of 1500 kW turbine technology.

Germany has the third largest total installed wind power capacity with a number of sophisticated wind power technologies.

**Table 5**
Source of technology for China's top 10 total installed capacity companies [8,57].

| Chinese company | Source company | Type (kW) | Source country |
|---|---|---|---|
| Sinovelwind Co., Ltd. | Wendtec Licensing | 1500 | Germany |
| | Wentec Joint-design | 3000 | Germany |
| Xinjiang Goldwind Co., Ltd. | Jacobs Licensing | 600 | Germany |
| | Repower Licensing | 750 | Germany |
| | Vensys Licensing | 1500 | Germany |
| Dong Fang Turbine Co., Ltd. | Repower Licensing | 1500 | Germany |
| | Wentec Licensing | 2500 | Germany |
| Guodian United Power Technology Co., Ltd. | Aerodyn Joint-design | 1500 | Germany |
| Mingyang Electric Co., Ltd. | Aerodyn Joint-design | 1500 | Germany |
| Xiangtan Electric Manufacturing Windpower Co., Ltd. | EWT Licensing | 2000 | Holland |
| Shanghai Electric Wind power Equipment Co., Ltd. | Dewind Licensing | 1250 | Germany |
| | Aerodyn Joint-design | 2000/3600 | Germany |
| Zhejiang Windey Co., Ltd. | Repower Licensing | 750/800 | Germany |
| | GH Joint-design | 1500 | UK |
| China Creative Wind Energy Co., Ltd. | Independent R&D | 1500/3000 | China |
| CISC (Chongqing) Haizhuang Windpower Equipment Co., Ltd. | Frisia Licensing | 850 | Germany |
| | Aerodyn Joint-design | 2000 | Germany |

Furthermore, Germany has released a number of policies to encourage the research and development of wind power. These include research cooperation and technology licensing, e.g. R&D subsidy, low rate loans and special cooperation projects that both German and foreign companies are eligible to apply [58]. Therefore, a lot of wind power technologies in China are licensed from Germany. Furthermore, both Germany and China benefit from the expansion of Chinese wind power industry due to wind power R&D spillover. Similarly, cost of wind power installed in Sweden has been heavily influenced by R&D expenses in Denmark, given that most turbines used in Sweden are Danish [59]. Indeed, it is a common phenomenon in the wind power industry. Countries import from turbine-producing countries and thus benefit from the R&D efforts in the producing countries.

In China, the Government guides the future direction of wind power industry. In 2008, Chinese Ministry of Finance released the Interim Administration Measures of Special Funds for Wind Power Equipment Industrialization. It is clearly stipulated that the enterprises are eligible to apply for 600 Yuan financial subsidies per kilowatt, if their wind power turbines or key components are newly developed and have achieved industrialization [56]. This financial subsidy is paid for the initial 50 wind power turbines or key components of units above 1 MW. Accordingly, it is probably fairly to say that that large scale wind power is the future direction of for the wind power industry in China.

### *5.3. Tariff policy to encourage the importing of wind turbine equipment*

The vast majority of Chinese wind power equipment manufacturers lack R&D capability. Currently, 95% of Chinese wind power converters depend on imports [60]. Chinese WTMs have less funds and capacity to design core components themselves. Generally, most Chinese firms interested in developing wind power technology acquire wind turbine designs through licensing arrangements from foreign firms, which take shorter time and less money than designing themselves. Accordingly, the Chinese wind power industry is highly dependent on importing its core components.

In order to satisfy its domestic demand, China has formulated preferential import tariffs policies. In 2009, the Chinese government amended the “Import and Export Tariff of the People's Republic of China” to provide for a lower Provisional Import Tariff for wind power equipment and key components (see Table 6). As shown in Table 6, the import provisional tariff rates of wind power equipment and core components range from 1% to 7%. Of particular note is the especially low tariff rate for special parts of generators and control systems. This tariff policy motivates manufacturers to import core components and to assemble wind turbines. This mitigates issues associated with the weak R&D capability within domestic WTMs.

The Chinese government has recently adjusted import tariff rates for wind turbine equipment of different capacity due mainly to the enhancement of manufacturing technology and production capacity of wind turbines up to 2 MW. In 2012, the Ministry of Finance, the Ministry of Industry and Information Technology, the General Administration of Customs and the State Administration of Taxation jointly issued a notice to adjust the key technical equipment import tax policy. New equipment and products, core components and raw materials imports, non-tax-free devices and products imports will be effective from April 1, 2012 [62]. The adjustment for wind turbine equipment is shown in Table 7. The import tax policy has significant changes, mainly around the raising of import quotas for single unit wind turbines from 1.5 MW to 2 MW. This means that wind turbine units capacity below 2 MW no longer enjoy the preferential policies of the exemption and import value added tax. This suggests that the manufacturing technology of wind turbines with a production capacity of 2 MW

**Table 6**
The provisional import tariff for Chinese wind power equipment and key components [61].

| Types of wind equipment | Most favored nation import rate (%) | Provisional import tax rate (%) |
|---|---|---|
| Hydraulic power device | 14 | 7 |
| Alternator | 10 | 5 |
| Wind generator unit | 8 | 5 |
| Drive parts | 8 | 4 |
| Control system | 7 | 4 |
| Special device of wind generator | 3 | 1 |

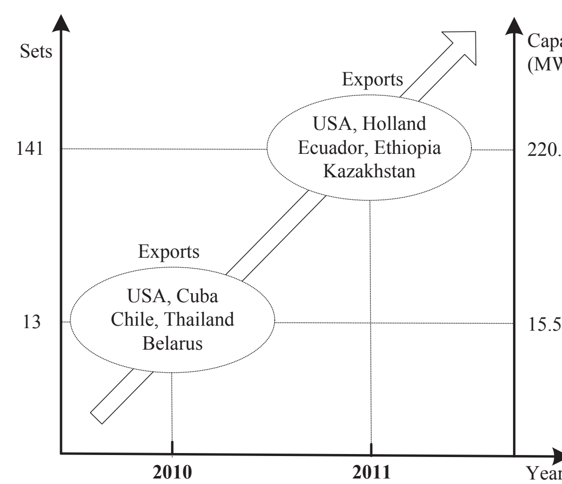


**Fig. 3.** Exports of Chinese wind power turbines in 2010–2011 [64,65].

**Table 7**
Import tariff policy adjustment of key technical equipment for wind power [62].

| Machines and parts | Technical specifications | Sales requirements | Status |
|---|---|---|---|
| Wind turbine generator unit | Generator capacity≥2 MW | Machines sales≥150 sets (No sales requirements≥2.5 MW) | Adjust |
| Blade, gearbox, generator | Generator capacity≥2 MW | Blades annual sales≥300 sets; Generator annual sales≥100 sets; Gearbox annual sales≥100 sets (No sales requirements≥2.5 MW) | Adjust |
| Offshore and intertidal wind turbine installation vessel | Lifting capacity≥500 t; Offshore wind generator capacity > 5 MW | No sales requirements | New |

has improved. However, wind turbines with a capacity greater than 2.5 MW are still dependent on imports. Clearly, the manufacturing capacity of large scale wind turbines still needs improvement.

Offshore wind power production has a number of advantages over on shore production. These include stronger and more reliable wind velocities, distance from residential areas and no competing demand for land [63]. It is worth noting that China has stipulated shipping requirements of “lifting capacity≥500 t and an offshore wind generator capacity of more than 5 MW” in the adjustment policy. Meanwhile, Chinese WTMs have made a breakthrough in terms of offshore wind technology innovation with Sinovel developing a 6 MW offshore wind turbines with independent intellectual property rights.

### 5.4. China's attempts to export wind turbines

In recent years, Chinese wind turbine manufacturers have implemented an “outlook” strategy to explore overseas markets. Leading enterprises such as Goldwind, Sinovel and Dongfang Turbines have formulated overseas development strategies.

Currently, Chinese WTMs are within the initial stage of exporting with small numbers of wind turbines being shipped to a few countries. As shown in Fig. 3, China began to export wind turbines in 2010 with the total amount of exports being as small as 13 sets to 5 countries. By 2011 exports of units and total capacity had increased by more than 10 times that of 2010. The capacity of single unit wind turbines increased from less than 1 MW to 1.5 MW. However when compared to that of European countries, Chinese WTMs exported fewer single lower capacity single units with comparatively lower level of technology.

China implements a preferential tax refund policy for wind turbine exports. As shown in Table 8, the refund tax rate of wind equipment export is 17%. In 2011, a total of 141 sets of wind turbines were exported with an average price of 2.48 million US dollars. As a result, the Chinese WTMs received 50.8 million US dollars of tax refund. This policy provides income protection for domestic wind turbine exporters as well as encouraging the export market.

Similarly, the exporting of wind turbine equipment is important for Chinese wind turbine manufacturers (WTMs). According to statistics from the China Chamber of Commerce for Import and Export of Machinery and Electronic Products, exports of wind turbine parts reached 627 million US dollars, which is equivalent to 2 times that of wind turbine exports [67].

Currently Chinese wind power equipment exports are facing serious challenges. In 2011, the United States Government questioned the subsidy of Chinese wind power equipment exports and subsequently carried out anti-subsidy and anti-dumping investigations [68]. As a result of preliminary rulings, some Chinese firms were provisionally imposed with anti-dumping duties of 20.85% to 72.69%. The United States is the major export market for Chinese wind power equipment. The implementation of anti-subsidy and anti-dumping rules has weakened the cost advantage of Chinese wind power equipment and has made it more difficult for Chinese enterprises to export their products.

**Table 8**
Wind power generation equipment export tax refund rate [66].

| Products | Value added tax rates (%) | Export tax rebate rate (%) |
|---|---|---|
| Controller | 17 | 17 |
| Facility | 17 | 17 |
| Component | 17 | 17 |

### 5.5. The Chinese Yuan (RMB) appreciation

Affected by such international factors as the global financial crisis, the exchange rate of the RMB is on a descending curve. From 2007 to 2012, the exchange rate of US dollar against RMB presents an overall downward trend, decreasing from 1:7.4 to 1:6.2. The exchange rate of the Euro to RMB similarly fell from 1:11 to 1:8. This RMB appreciation has had some influence on the Chinese wind power industry.

The adverse effects of the RMB appreciation include some short-term export exchange loss and negative impacts on the long-term export competitiveness [69]. The appreciating RMB has weakened the cost advantage of Chinese wind power equipment exports. Shipping is the most common method for transporting wind power equipment. The long shipping cycle demands a comparatively longer period of time for exporters to recover the capital cost. Therefore, the exporters need a hedging strategy to mitigate risks associated with the exchange rate fluctuations, which in turn increase the financial cost. As for foreign CDM investors, the appreciating RMB means a higher cost to purchase the CERs. Thus, it will reduce the attractiveness of Chinese CERs and hinder the CDM application of Chinese wind power projects. Besides, due to the RMB appreciation, Chinese wind power equipment exporters have altered the overseas market focus from the United States to developing countries, i.e. Thailand and Ethiopia.

On the positive side, the appreciating RMB will encourage the import of wind turbine core components and promote the overseas merger strategy [70]. The cost of wind turbine components imports may decrease slightly, as will the domestic wind turbine cost. The import price per set of wind turbines is 1.35 million Euros per megawatt on average [71]. The exchange rate in 2007 was 1:11 whereas in 2012 it was 1:8. This represents a saving in terms of the import price of 4.05 million RMB in 2012 alone when compared to 2007. Therefore, the appreciation of the RMB will assist the domestic wind power industry to import advanced equipment and technologies. Meanwhile, Chinese wind power enterprises are able to merge or acquire overseas enterprises with less cost.

## 6. Conclusions

China has surpassed the United States to become the largest wind power country in terms of accumulated installed capacity. China is also the world's largest wind power market with massive development potential. The rapid growth of the Chinese wind power industry is dependent on the guidance and incentives provided by the government. However, it is worth noting that international forces are playing an increasing critical role in the development of that industry.

This paper has developed a comprehensive model to explore the interactive function between the Chinese wind power industry and international forces. The model consists of three subsystems, i.e. the international cooperation subsystem, the CDM subsystem and the import/export subsystem.

In the international cooperation subsystem, China is increasing its participation in the International Conference on Climate Change and is seeking to cooperate with other countries in the field of renewable energy and how to deal with climate change. The joint R&D mechanism, ranging from intergovernmental to inter-enterprise cooperation provides a platform for the Chinese wind power industry to more frequently communicate with the international community thereby facilitating the procurement of advanced technologies and the funds necessary for the development of the industry. Similarly, the information sharing platform provides more information about the Chinese wind power market

to foreign investors minimizing their risks and enabling them to make smarter investment decisions.

The CDM subsystem provides financial and technical support to the Chinese wind power industry. The CDM revenue accounts for about 10% of the pre-tax profits of Chinese wind power developers. CDM also promotes the diffusion of wind power technologies. However, there is no evidence that the CDM promotes wind power technological innovation. China is the largest CERs provider thereby enabling strong support to the world carbon financial markets. However, Chinese CDM project applications are facing significant obstacles, mainly due to the uncertainty resulting from the recent (end of 2012) expiration of the first commitment period of the Kyoto Protocol.

Opportunities and challenges co-exist in both the import and export sides of the Chinese wind power industry. By entering the Chinese market, (and taking a share of that market) international WTM shave formed both a competitive and co-operative relationship with the domestic WTMs. Importing core technologies from overseas has played a critical role in satisfying the growing demands of the Chinese wind power market. However this has also resulted in inefficiency due to some duplication of efforts. China has formulated a series of import tariff policies to promote the development of the wind power industry. China imposes low provisional import tariffs on core technology and components related to wind power. The import tariff has been adjusted along with the enhanced independent innovation within domestic WTMs. The Chinese wind power industry is moving in a positive direction as it goes from relying on imports to exploring the possibility of exports. The scale and cost advantages of the Chinese wind power industry are favorable conditions for exports. Furthermore, exporting helps to mitigate overcapacity issues existing within domestic WTMs. Most Chinese wind power products are exported to the United States and developing countries located in South America, Africa, and Central Asia. Finally, the appreciation of the RMB against many international currencies presents a significant barrier to exports and CDM project applications. On the other hand this appreciation has also resulted in the lowering of the cost of imports and is more favorable to overseas mergers and the acquisitions strategies of domestic WTMs.

This interactive mechanism model helps wind power investors and operators gain a better understanding of how the Chinese wind power industry is influenced by international forces. This model can also be applied to other renewable energy sources. Besides, other counties may also take a reference, which are in the familiar situation to develop the wind power industry.

## Acknowledgments

This study is part of research projects supported by the Humanities and Social Sciences Planning Fund of Ministry of Education of China (No.12YJAZH205), the Natural Science Foundation of Hebei Province of China (No.G2012502065), and the Beijing Philosophy and Social Science Planning Project (No.12JGB067). The authors would like to express their gratitude for the support of these funding authorities.

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